period of displacement). General uplift of the Vanch Range (isolation of the Vanch anticline as such) produced a southward-dipping structural gradient, which caused further southward sliding of allochthonous rock masses under gravity (absolute southward displacement of the allochthon).

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SUBSURFACE HEAT FLOW IN THE BIBIEYBAT OIL AND GAS FIELD[1]

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The Bibieybat oil and gas field is in the southwestern coastal part of the Apsheron Peninsula. Sediments of the Surakhany suite and the Akchagylian stage are exposed at the crest of a fold. There are also deposits of Quaternary and Apsheronian age. The field is confined to an asymmetric brachyanticline, complicated by several faults [1]. In the upper division of the productive formation are cross faults dipping south, with a displacement of as much as 35 to 50 m. At the base of the productive formation are three reverse faults dipping east. The crest of the fold is complicated by the buried (fossil) Bukhta mud volcano.

The Bibieybat field has been carefully studied by many investigators. In particular, the subsurface geothermal state of the field is well known [3,4]. However, for lack of data on the vertical variation in thermophysical properties of rocks, the energy lost through heat conduction could not be estimated quantitatively.

We investigated the thermophysical properties of clay, siltstone and sandstone from the Sabunchi, Balakhany, "Pereryv," NKG, NKP, KC and PK suites. Because of the limited number of specimens cored during well drilling, we had to prepare a composite thermophysical section from data on several fields of the Apsheron Peninsula. In calculating the average thermal conductivity of rocks in wells, we allowed for the thickness of the sequence and for the sandiness of individual suites in the productive formation.

We determined the heat flow in 15 wells at the Bibieybat field. Borehole temperatures were measured after they had been out of service for a long time.

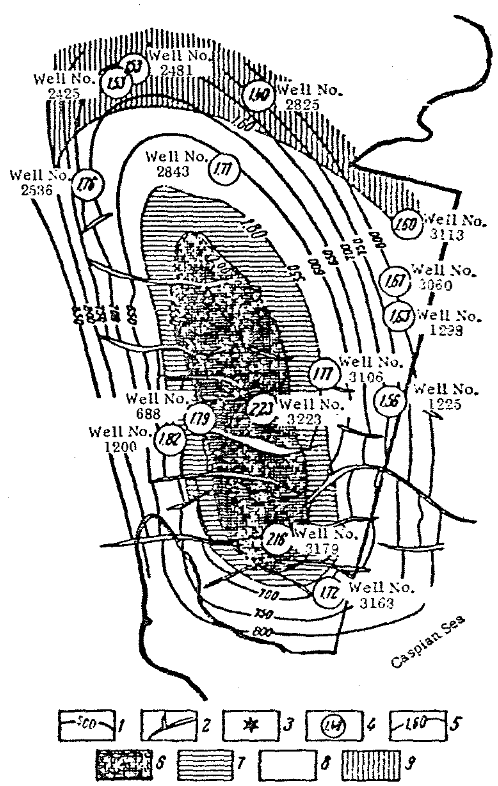

Fig. 1. Map of heat flow at the Bibieybat field. 1) Structure contours on base of bed X, Sabunchi suite; 2) faults; 3) Bukhta fossil mud volcano; 4) heat flow in wells, 10^{-6} cal/cm^2·sec; 5) lines of equal heat flow; 6) zone with a heat flow of $2.0 \cdot 10^{-6}$ cal/cm^2; 7) same, 2.0 to $1.8 \cdot 10^{-6}$; 8) same, 1.8 to $1.6 \cdot 10^{-6}$; 9) same, 1.6 to $1.4 \cdot 10^{-6}$ sec.

[1] Translated from: Teplovoy potok iz nedra neftegazovogo mestorozhdeniya Bibieybat. Doklady Akademii Nauk SSSR, 1970, Vol. 190, No. 1, pp. 176-179.

Table 1

	Crest near mud volcano	Near crest		West limb	East limb				Southeast pericline		Northwest pericline				
	No. 3223	No. 688	No. 3106	No. 1200	No. 1225	No. 1298	No. 3060	No. 3113	No. 3179	No. 3163	No. 2843	No. 2536	No. 2425	No. 2481	No. 2825
Range of temperature measurement, m	300—500	400—600	300—1265	200—1475	525—1425	765—1485	100—1100	200—1500	400—1565	300—1580	400—1340	300—1515	300—1490	300—1450	155—1650
Temperature at the beginning and end of range	27.6—36.2	28.8—37.2	25.3—55.4	23.8—61.4	36.7—61.8	42.9—63.6	25—54.3	25.4—60.7	28.3—59.3	25.4—62.7	31.2—54.3	24.2—60.7	23.9—55.9	26.6—57	26.6—60.3
Age of sediments in the measured temperature range	Sabunchi suite	Surakhany suite to Sabunchi suite	Sabunchi suite to NKP suite	Surakhany suite to NKP suite	Sabunchi suite to NKG suite	Sabunchi suite to NKG suite	Apsheronian stage to Balakhany suite	Surakhany suite to "Pereryv" suite	Sabunchi suite to NKG suite	Surakhany suite to NKP suite	Sabunchi suite to NKP suite	Surakhany suite to "Pereryv" suite	Surakhany suite to NKP suite	Surakhany suite to NKP suite	Surakhany suite to Kirmakinskaya suite
Average geothermal gradient, deg/m	0.0434	0.0357	0.0310	0.0306	0.0266	0.0279	0.0311	0.0281	0.0365	0.0286	0.0274	0.0301	0.0263	0.0263	0.0240
Average thermal conductivity in the section, kcal/m·hr·deg	1.85	1.81	2.05	2.10	2.11	2.10	1.94	2.05	2.13	2.16	2.29	2.10	2.10	2.10	2.10
Heat flow, 10^{-6} kcal/cm^2·hr	2.23	1.79	1.77	1.62	1.56	1.63	1.67	1.60	2.16	1.72	1.71	1.76	1.53	1.53	1.40
Heat flow, 10^{-2} kcal/cm^2·hr	8.03	6.46	6.36	6.53	5.61	5.86	6.03	5.76	7.77	6.18	6.14	6.32	5.52	5.52	5.04

Because wells are spaced uniformly across the structure, we have been able to locate several interesting features in the heat flow distribution (see Table 1). As already noted, the crest of the fold is complicated by a mud volcano. Eruption products, e.g., mud breccia, are found at the surface, in joints and as subsurface offshoots in individual suites of the productive formation near the vent. At well No. 3223, in the immediate vicinity of the mud volcano, the heat flow is maximum.

It should be noted that near the crest of the fold, and in places on the west limb, the variable sandiness of the section is reflected in the average geothermal gradient and thermal conductivity of rocks.

The lower thermal gradient below the east limb (compared with the west limb) reflects the difference in their structure: the east limb is gentle (25° to 30°), but the west limb is relatively steep (as much as 50°) and in places resembles a flexure. The presence of mud breccia near the top of the west limb (at the base of the "Pereryv" suite) is noteworthy, and indicates that a mud volcano was active here.

Our data show very clearly that there is an old mud volcano at the southeast pericline (well No. 3179). Previous geologic work [2] has proved that the mud volcano was submarine and active before the deposition of the "Pereryv" suite. Away from the old volcano, toward the more steeply dipping periclinal end of the structure, the subsurface thermal gradient decreases. However, the heat flow along the southeast pericline exceeds that in wells at the northwest end of the fold, which are in a similar setting (see also Fig. 1, well Nos. 2425, 2481 and others).

It should be emphasized that the southeast pericline is steep and highly deformed, whereas the northwest pericline is gentle and somewhat extended. This structural difference is clearly reflected in the heat flow (see Fig. 1). The geothermal gradient at the northwest end of the fold is lower than that at the southeast pericline (see Table 1).

Thus, our data on the Bibieybat oil and gas field show that, as would be expected, the heat flow is greatest at the crest of the structure. But the heat transport is still more intense near the volcano. The roots of this volcano are in sediments of Paleogene and, perhaps, Late Cretaceous age. The vent of the Bukhta volcano is surrounded by zones of maximum rock shattering. These zones are convenient pathways for the alkaline water from the lower division, propelled by the high pressure, to penetrate up to bed V (well No. 1) of the Sabunchi suite [5]. It should be noted that in the Bibieybat field hard calcium chloride water is replaced by alkaline sodium bicarbonate water primarily at the top of the Balakhany suite, at and below a depth of 400 to 500 m. The vent of the mud volcano acts as a kind of channel, along which the transport of subsurface heat is more intense. This produces the unusual distribution of subsurface heat evident in the sedimentary covers in the vicinity of mud volcanoes.

The above facts confirm previous conclusions [6] that it is possible to search for structures and locate faults by measuring heat flows even in shallow wells.

The detailed study of the heat flow in the vicinity of mud volcanoes apparently yields reliable supporting data for assessing the stratigraphic depth of their roots. It also provides a firmer and more reliable basis for the search for thermal water.

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